

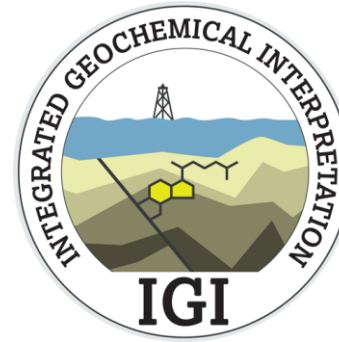
Modelling Migration and Trapping of Natural Hydrogen in Sedimentary Basins

Kinedyn Solutions, Bremen, Germany



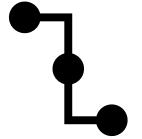
Javier García-Pintado
jgarciapintado@marum.de
Marta Gussinyer-Pérez

Integrated Geochemical Interpretation - UK



Tiago Abreu Cunha
tiago@igiltd.com
Marianne Nuzzo
Dan Cornford
Mischa Gehlen

OBJECTIVES



Use box models to understand the mechanisms that control migration and trapping of H₂; efficient and extensive testing of model setups and parameters



Compile quality-controlled gas databases and build a property model to assist in the interpretation of the geochemical systems



Build basin-scale models to assist in exploration and de-risk prospects

MOTIVATION



Hydrogen usage in the energy mix is predicted to increase 5-10 fold in the next 50 years, and natural H₂ exploration involves low water and energy consumption



There is widespread evidence of natural hydrogen occurrences (generation), migration and seeps



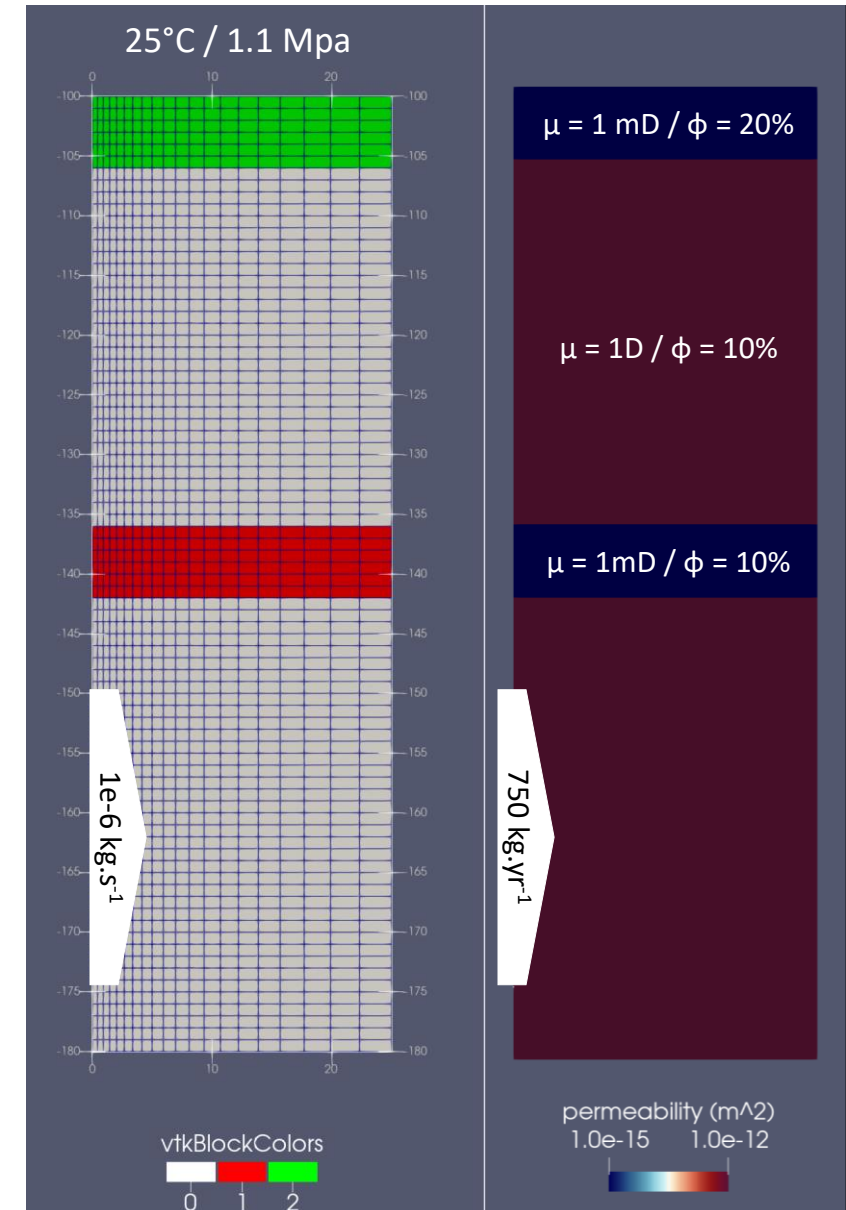
There are only sparse evidence of high H₂ concentrations in sediments and crystalline rock underground

Box-Size Numerical Experiments on H₂ Migration and Trapping: Model Setup

- ❑ 25 m * 80 m high-resolution box model with two lower permeability zones
- ❑ Injection of H₂ along 24 m on the left side near the lower reservoir
- ❑ Model runs for 10 yr reaching a dynamic equilibrium

- ❑ Two-phase flow with pure water and Hydrogen (or methane) components
- ❑ Equations of state for density, viscosity & specific enthalpy
- ❑ Migration by advection in gas & liquid phase plus diffusion in the liquid phase
- ❑ Henry coefficient (temperature-dependent) controlling the equilibrium between the gas and dissolved mass fractions
- ❑ Corey (1954) effective-saturation dependent relative permeability; residual saturations are 0.15 for liquid and 0.05 for gas
- ❑ Van Genuchten (1980) capillary pressure-saturation

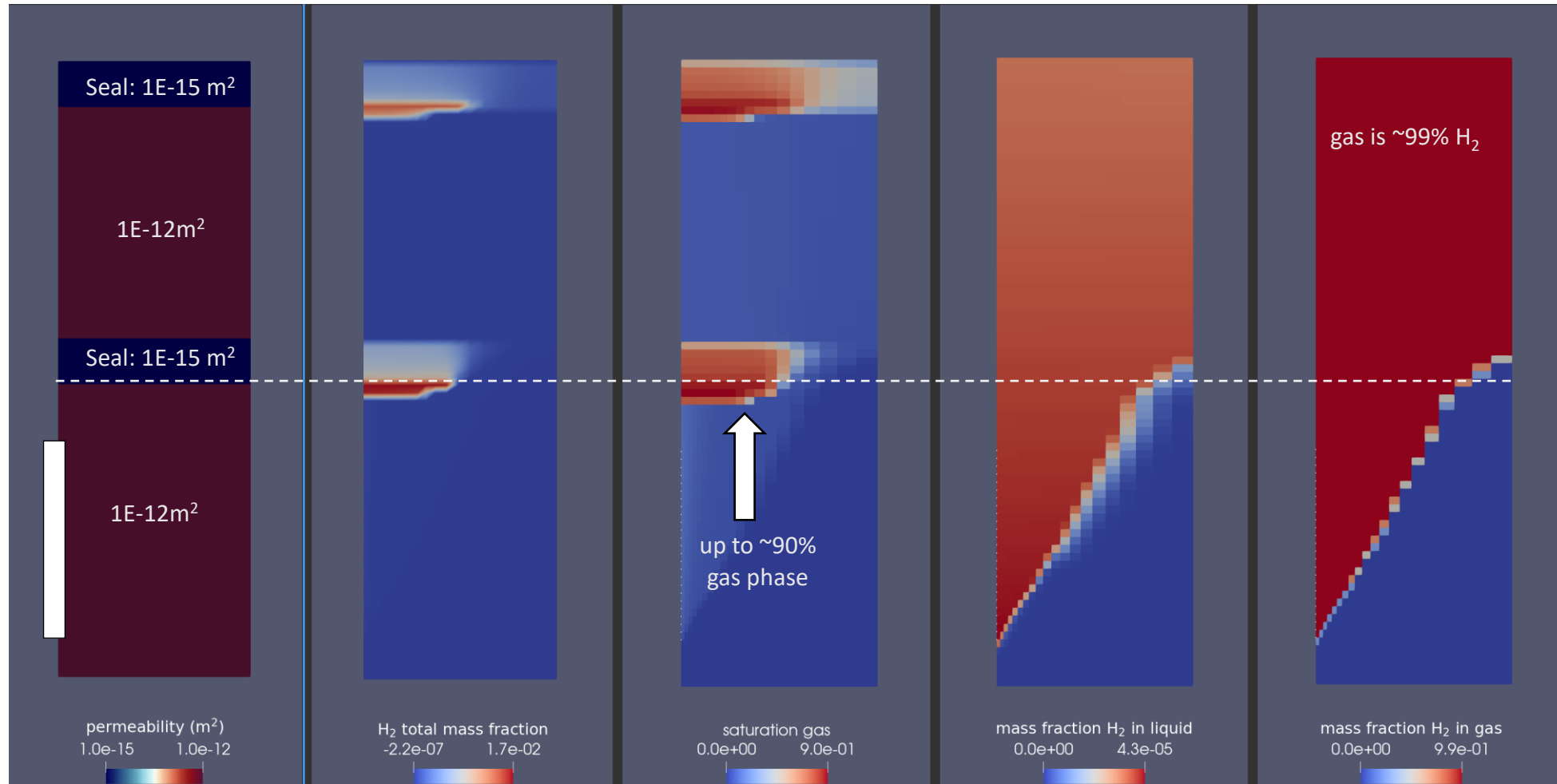
<https://igiltd.com/news/modelling-hydrogen-migration-and-trapping-phase-1/>



Box-Size Numerical Experiments on H₂ Migration and Trapping: Near Surface Model

PERSPECTIVE: 750 kg.yr⁻¹ is ca. 3-4 orders of magnitude of the outgassing measured in the Samail ophiolite in Oman (Leong *et al.*, 2023), although this might only be a fraction of the total generated, and 3-6 orders of magnitude lower than industrial hydrogen storage (e.g. Madhi *et al.*, 2021).

- ❑ Dynamic equilibrium reached after < 10 yr
- ❑ Most of the gas in the model is H₂ (minor H₂O)
- ❑ Very low quantities of dissolved H₂ due to low solubility
- ❑ The predicted storage increases 3x fold for the gas mass and ~10x for the dissolved H₂ at 1 km depth
- ❑ Tests with CH₄ predict advection velocities approximately 3x lower.



PERSPECTIVE: The Bourakebougou discovery is 98% pure H₂ (Prinzhofer *et al.*, 2018).

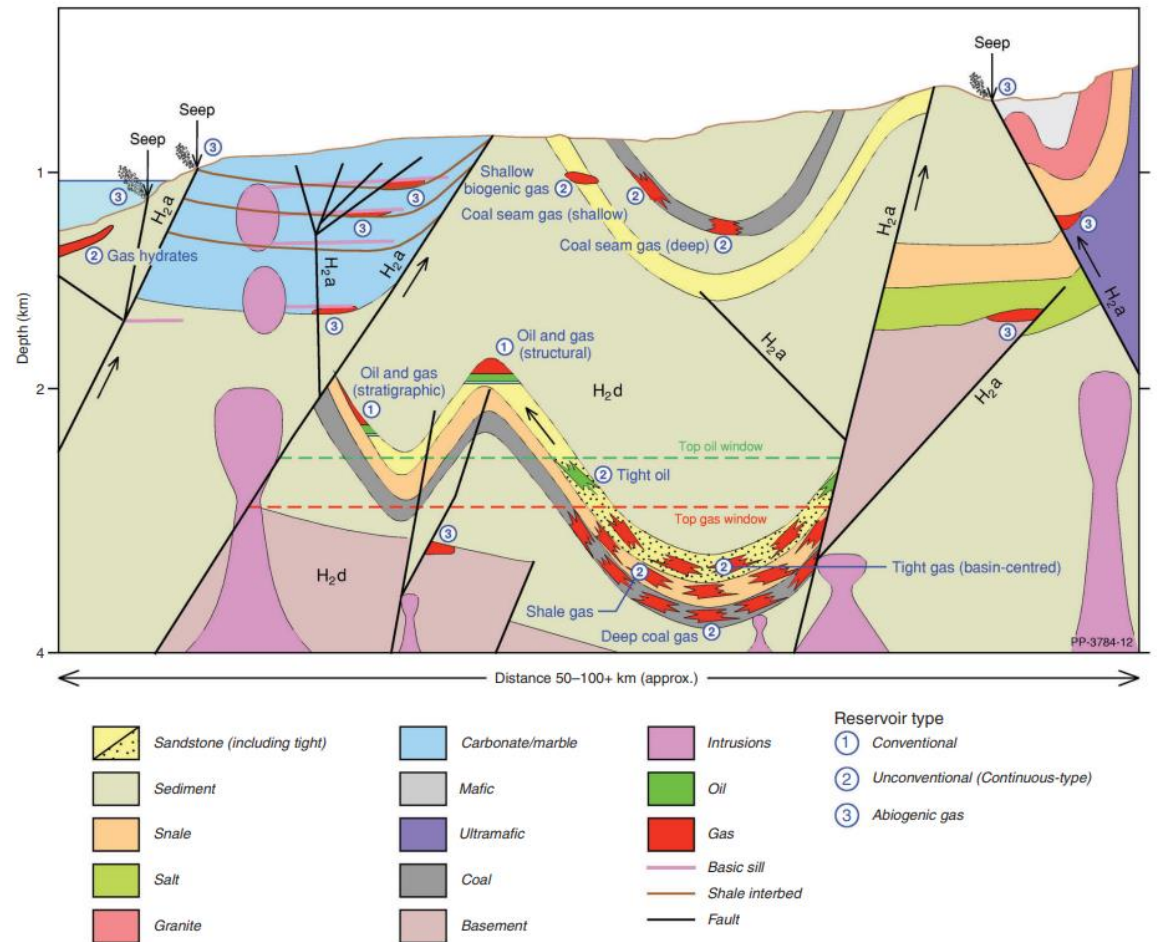
Next Steps with Box-Size Numerical Experiments and Going Natural

Next steps in the box (test) models

- ❑ Run the models over geological timescales
- ❑ Parameterize other processes, such as adsorption, biological sinks and hydrodynamics
- ❑ Test multiple gases systems (ie. H_2O , H_2 and CH_4)
- ❑ Test sensitivities to a variety of realistic geological setting, such as lithologies, P-T conditions and H_2 generation rates

Going natural

- ❑ Build basin-scale models
- ❑ Compile gas (compositions, isotopes) datasets
- ❑ Calibrate the models to observations/data
- ❑ Test model scenarios to assist (de-risk) natural hydrogen exploration
- ❑ Test scenarios to assist induced hydrogen exploration



From Boreham *et al.* (2021)

Project Timeline

Time / Project elements	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Databasing of gas geochemistry								
Geochemical interpretation								
Sensitivity tests with box-size models								
Basin structural-thermal setup								
Basin-scale model: Analysis of model requirements								
Basin-scale model: Implementation of model components								
Basin-scale model: Integration and numerical testing								
Basin-scale model: Testing of model scenarios								
Analysis of model results & reporting								

Data and Inputs

- ❑ Available gas geochemistry and isotopic data. Where available we can also use the publicly available geochemistry data.
- ❑ A basin transect with interpreted stratigraphic horizons, lithologies and structural elements. Ideally, the model would be built along a depth converted seismic profile where we could define all elements of the play.
- ❑ Borehole data if available, including reports and logs, and temperature data for thermal calibration of the mode

Main Deliverables

- ❑ Gas geochemistry and isotopic database in pIGI format (also available in Excel and ASCII formats, as required)
- ❑ Geochemistry interpretation in PPT and PDF formats, providing an insight on the gas systems and their maturity, sources and sinks.
- ❑ All plots, videos and final report on the numerical model, with interpretation of results, insights on the tested modelling scenarios, and analysis of risk in the potential hydrogen prospects.
- ❑ Workshops with the Team every 3 months (or as requested) to discuss the work progress and the strategy moving forward.

Kinedyn software

- ❑ Any modification of Kinedyn software that may be required to achieve the project deliverables during the duration of this project will remain the sole intellectual property of Kinedyn Solutions

Project Cost

- ❑ The total cost of the study is USD 120,000 (exclusive of tax and any travelling expenses, billed at cost).

R&D Project Team

Dr. Tiago Cunha: Senior petroleum systems analyst, with 15+ years' experience in BPSM, integrating geology, geochemistry and geophysical data in sedimentary basins worldwide.

Dr Marianne Nuzzo : Senior organic- and bio-geochemist with over 20 years of experience in gas and petroleum with a specialism in hydrocarbon gas geochemistry. She has been working for the Oil & Gas (O&G) industry since 2013.

Dr. Dan Cornford: Experienced statistician with 30 years (20 academic, 10+ industrial) experience in machine learning, uncertainty quantification, model calibration and data assimilation. A firm believer in pragmatic Bayesian approaches to using data and models.

Dr. Javier Garcia-Pintado: Mining Engineer, with 20+ years of experience in code development and modelling of various components of the Earth system, including hydrogeology, flood-forecasting and geodynamic-hydrological interactions. Strong experience in model-data integration and data assimilation.

Prof. Marta Perez-Gussinye: Geophysicist with 25+ years of experience in seismic methods and geodynamical modelling. Published several seminal papers on the development of passive margins and the mechanics of lithospheric deformation. Recent research encompasses the implications of geodynamics for natural H₂ production.